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FIRE REGIMES AND THEIR RELEVANCE TO ECOSYSTEM MANAGEMENT[1]

by James K. Brown[2]

ABSTRACT: A fire regime classification that recognizes stand-replacement, nonlethal understory, mixed and variable fire severities is discussed as a simplified approach for communicating widely about the natural role of fire. Examples of the fire regime types are provided. Five challenges to meeting the goals of ecosystem management based on knowledge of fire regimes are discussed. They are: (1) restoration of nonlethal fire regime forests, (2) proper removal and retention of dead biomass, (3) managing for large stand-replacement disturbances, (4) managing for diverse stand structures in mixed and variable fire regime types, and (5) maintaining grasslands threatened by encroachment of woody vegetation.

INTRODUCTION

The importance of the role fire plays in ecosystems throughout the world is becoming commonly accepted by ecologists and many natural resource managers. Fire's role is complicated because it influences and controls many ecosystem processes and characteristics such as dry matter and nutrient cycling, productivity, plant species composition and community structure, and fuel accumulations (Wright and Heinselman 1973). The list certainly can be expanded. How do we categorize the many-faceted role of fire? We need a way to simplify and facilitate communications about fire in order to effectively plan and manage for wildland fire in many different ecosystems. The concept of fire regimes can help meet that need. Knowledge of fire regimes is increasingly recognized as a critical basis for ecosystem management. The purpose of this paper is to suggest a simplified classification of fire regimes and to discuss the relevance of fire regimes knowledge to ecosystem management and major challenges faced in applying it.

Fire Regime Classification

A fire regime refers to the nature of fire that occurs over time, usually the past several hundred years, in a specific region. The concept is a synthesis of broad ecological and physical principles into a few categories. It lends a semblance of order to an extensive but often confusing and sometimes contradictory literature on fire (Pyne 1984). Classifications of fire regimes can be based on the characteristics of the fire itself or on the effects produced by the fire (Agee 1993). Fire regimes, introduced first by Heinselman (1978), were based on a classification of fire intensity (crowning or surface fire), size of ecologically significant fires, and fire frequency

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or return intervals (Fig. 1). Other suggested components include pattern of burn, depth of burn, and season of burn (Kilgore 1987).

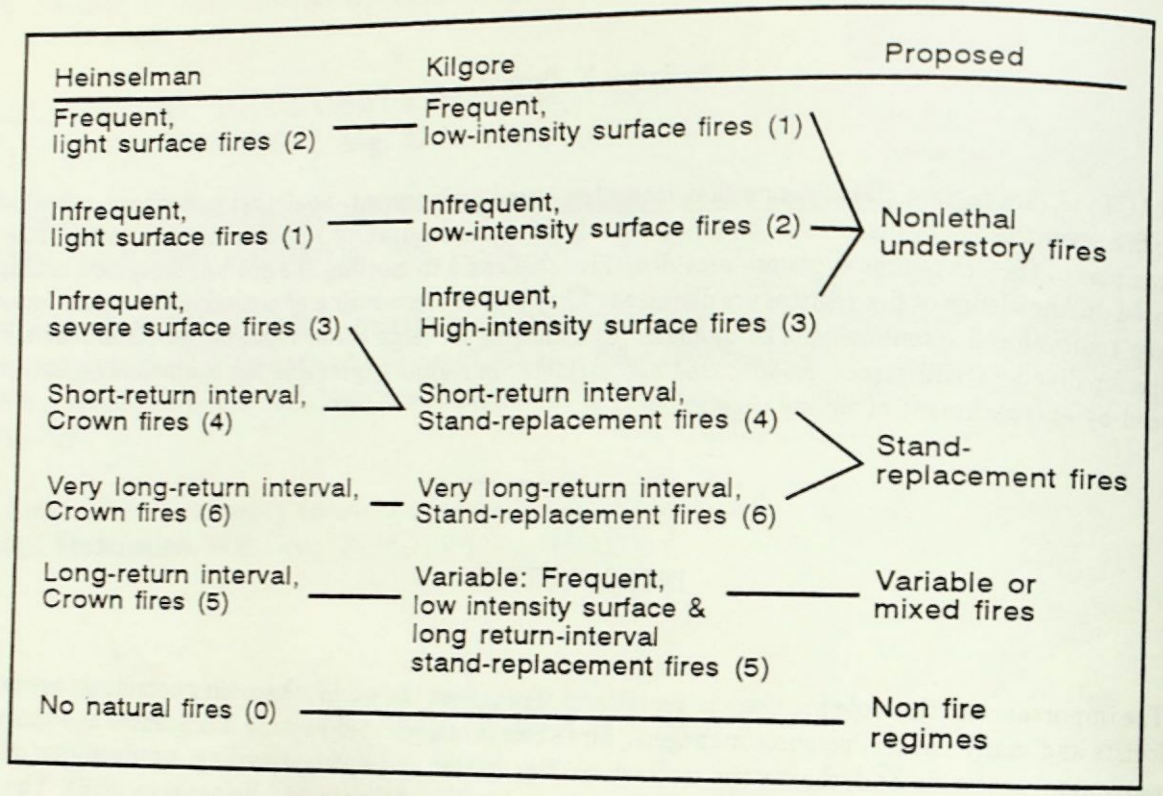

Figure 1. Comparison of fire regime classification of Heinselman (1978), Kilgore (1981), and a proposed simplified version.

Fire intensity as used in Heinselman's (1978) classification relates only generally to fire severity. Kilgore (1981) showed this relationship in his modification of Heinselman's fire regimes by referring to mortality of the primary tree cover as stand replacement (Fig.1). But, a wide range of fire intensities including crown fire and surface fire can result in complete or nearly complete mortality of aboveground vegetation. The result is still stand replacement. Stand replacement depends on both fire intensity and fire resistance of dominant vegetation. For example, a frequent, low-intensity fire regime characterizes a nonlethal understory fire occurring in a long-needled pine forest as well as a stand-replacement fire occurring in a short-grass prairie ecosystem. Another example is that a high intensity fire may mean stand replacement in a lodgepole pine forest but a nonlethal understory fire in a coast redwood forest.

Use of fire severity as a key component in describing fire regimes is appealing because it relates directly to effects of disturbance, which is of paramount importance for communication among a wide range of professionals and interested citizens who are concerned with ecosystem management. Severity of fire reflects the immediate or primary effects of fire that result from intensity of the propagating fire front and heat released during total fuel consumption. Plant mortality and removal of organic matter are the primary effects. Fire intensity, however, requires different interpretations in different ecosystems.

Other important components to complete a description of fire regimes are fire frequency and fire size. Size of significant fires provides insight into the pattern of burn. The important feature here is the size of

burned patches since a single fire may be comprised of one or more patches.

The classification proposed in Figure 1 emphasizes fire severity instead of fire intensity. Fire frequency is considered separately and not combined with fire severity to form a dual component classification. Fire frequency is best described as a mean and range of fire return intervals based on an examination of fire history for individual ecosystems. The simple fire regime classification will be suitable for many purposes. A more elaborate classification may be appropriate for use among specialists.

The classification of fire severity and hence fire regimes is based on what happens to the dominant vegetation. If most of the dominant aboveground vegetation (approximately 80% or more of the dominant cover or biomass) dies as a result of fire, it is considered stand replacement. If most of the dominant vegetation survives, it is considered nonlethal understory fire. If severity is in between it is classified as a mixed regime, which consists of individual fires that alternate between nonlethal understory burning and stand-replacement creating a fine-grained pattern of young and older trees. This type of fire, which causes intermediate levels of plant mortality, has not been described in previous fire regime classifications but probably occurs commonly. If severity differs between fires on the same landscape it is classified as a variable regime which typically consists of frequent, low-intensity surface fires and long-interval, stand-replacement fires (Kilgore 1987).

Although the concept of fire regime types was originally developed with forest vegetation in mind, it can also apply to nonforested vegetation types such as prairie, tundra, and savannah. If the dominant aboveground vegetation is killed by fire, the regime type is considered as stand replacement irregardless of the mechanisms of regeneration and speed of vegetative recovery. For example, since grass is the dominant vegetation in the short-grass prairie ecosystem and the aboveground parts are killed by fire, it is a stand-replacement fire regime type because the dominant vegetation has been replaced. Also, shrubland ecosystems typically experience stand-replacement fire regimes because the dominant shrub layer is usually killed back to growing points in or near the ground.

Fire Regime Examples

Some examples of fire regimes are described here to illustrate the classification. Note that some forest types that occur over a range of environmental conditions may be characterized by more than one fire regime type. Variability of fire regime within broad vegetation types is aptly discussed by Heinselman (1981) and Kilgore (1981).

NONLETHAL FIRE REGIMES

Ponderosa pine and Jeffrey pine.–Fires were frequent, with mean fire intervals between 5 and 30 years (Kilgore 1987; Arno 1994). Fires were low intensity underburns that were very large in areas where the cover type was extensive such as on high plateaus in the southwestern United States. In contrast, fires were probably small in rugged mountainous terrain where the flammable sites were confined to isolated dry sites on south-facing slopes.

Longleaf, loblolly, and slash pines.–Low-intensity fires in these pine types found on the coastal plain of southeastern United States probably occurred every 2 to 8 years (Christensen 1981). Fires apparently were primarily ignited by resident Native Americans. In the absence of frequent low-intensity fire, these stands tend to become dominated by shrubs and hardwoods.

STAND-REPLACEMENT FIRE REGIMES

Black spruce.–Natural fire cycles ranged from 50 to 100 years in northwestern Canada and up to nearly 500 years in parts of eastern Canada (Duchesne 1994). Fires were very large in size and usually occurred as a mixture of crown fire and severe surface fire that killed the dominant black spruce overstory (Heinselman 1981; Viereck 1993).

Lodgepole pine.–Average stand-replacement fire intervals ranged from 70 to 300 years throughout the Rocky Mountains in Canada and the United States (Arno 1994; Brown 1975). Fires were typically large in size and involved a mixture of lethal surface fire and crown fire.

Arctic tundra.–The fire cycle may have been as short as 100 years but was usually much longer (Viereck and Schandelmeier 1980). Fires, primarily of moderate intensity, killed all aboveground vegetation but seldom killed underground plant parts. Fire size varied from many small to medium-sized fires to some of very large size (Duchesne 1994).

Sagebrush-grass.–Fires occurred at an average frequency of 32 to 70 years (Houston 1973) and were of large size (Kilgore 1987). All aboveground vegetation was killed. Recovery included a period of domination by grasses and forbs.

MIXED AND VARIABLE FIRE REGIMES

Interior Douglas-fir.–Fires occurred at an average frequency of 25 to 100 years (Arno 1994). Burning patterns were complex in mixed regimes, leaving a fine grained mosaic on the landscape. Patterns may have been more regular in variable fire regimes. Tree mortality varied considerably over the landscape due to varying fire resistance and burning conditions.

Coastal Douglas-fir.–Variable and mixed fire regimes were the rule in the Douglas-fir type south from west-central Oregon, in drier areas farther north, and in Douglas-fir/hardwood types. Fire frequencies averaged 40 to 150 years (Arno 1994; Agee 1993). The cooler, wetter portions of coastal Douglas-fir were associated with stand-replacement fires.

Jack pine.–On dry sites fires recurred on an average of 15 to 50 years (Duchesne 1994; Heinselman 1983). Many jack pine trees survived creeping and low intensity surface fires creating a highly varied stand structure. The primary fire regime, however, was stand-replacement.

Lodgepole pine.–Similar to jack pine, a mixed regime is found on drier sites supporting lodgepole pine with fires occurring at an average frequency of 25 to 75 years (Arno 1994). Both variable and mixed regime types occur; however, the characteristic fire regime for most lodgepole pine forests is stand-replacement.

White and red pine.–Fire frequency varied widely throughout these forests with mean fire intervals ranging from 20 to 300 years (Duchesne 1994). For the Great Lakes-St. Lawrence forest region fire frequency averaged approximately 100 years. On dry sites, low-intensity fires occurred on a cycle of 20 to 40 years with high intensity fires every 100 to 200 years. Fires were of medium size (Heinselman 1981).

Ecosystem Management

Although a number of definitions of ecosystem management have been suggested, they all focus on providing a variety of resources within the limits and capabilities of ecosystems sustained over the long term. An important goal of ecosystem management is to retain structural and functional components across the landscape consistent with the capabilities of the ecosystem. Describing and understanding the capabilities of ecosystems requires knowledge of the composition, structure, and the functioning of essential ecosystem components. Since fire as a disturbance process is a major initiator and controller of ecosystem characteristics, knowledge of natural fire regimes is essential to understanding natural variability in ecosystem components and

processes (Swanson et al. 1973). Understanding natural variability provides a basis for designing management prescriptions and helps establish reference points for evaluating ecosystem management (Morgan et al. 1994).

Limitations to use of historical fire regime knowledge in ecosystem management need to be recognized. They include the following (Swanson et al. 1993; Morgan et al. 1994):

1. Difficulty interpreting past variability due to insufficient data.
2. Degree to which past and future environmental conditions may fall outside the established range in historical conditions.
3. Extent to which the range of ecosystem conditions desired by society differs from natural variability.

Keeping limitations of knowledge about natural fire regimes in mind, managing ecosystems to avoid substantial departures from a natural range of variability seems to be a wise course of action. Many solutions on the landscape are possible, which presents land managers with complex decisions. The challenge is to provide for biological diversity and essential ecosystem processes while meeting the resource needs of society.

CHALLENGES IN APPLYING FIRE REGIME KNOWLEDGE

Several widely applicable problems and related challenges to meeting the goals of ecosystem management based on knowledge of fire regimes are described below. Approaches to solving the problems will vary depending on whether lands are zoned as wilderness and natural areas or for nonwilderness uses (Brown and Arno 1991). On nonwilderness lands, fire and cutting should be considered together as agents of disturbance.

1. *Restoration of nonlethal fire regime forests*.–The effects of fire exclusion policies are most obvious in the nonlethal fire regime type where the current period without fire is much longer than the average fire return interval computed for the last few centuries (Arno and Brown 1991). For example, in ponderosa pine forests, the density and the abundance of more shade-tolerant tree species has increased. At the same time, tree mortality due to insect and disease attacks has dramatically increased. Fire hazard has increased substantially as live and dead fuels have accumulated (Mutch et al. 1993). Ponderosa pine has been greatly reduced in some areas where it is a seral species.

Lower tree densities and more open understories are needed to restore healthy conditions. The appropriate solution will depend on existing stand composition and structure and the social/political environment. In some cases, prescribed understory fire can be applied on a regular basis to maintain desirable conditions. In many situations, however, restoration of healthy conditions will require combinations of thinning, limited salvage, understory fire, and planting of ponderosa pine. Once established, healthy conditions can be maintained with repeated underburning and limited harvesting.

2. *Dead biomass and fuel management*.–Land managers must prescribe activities that avoid either removing or leaving too much dead biomass and live fuel. Dead trees, both standing and downed, are an important component of ecosystems. They are a source of nutrients, provide site protection, and support many different forms of animal life. But, when accumulated amounts of dead biomass and live fuel extend over large areas of the landscape, fire hazards become excessively high. Determining the quantity and form of dead biomass to leave on-site requires consideration of its ecological role and the need to avoid unacceptable risks of losing other ecosystem products, property, and human lives. Achieving the proper retention of dead biomass, especially where both harvesting and prescribed fire are planned, requires interdisciplinary judgement and landscape perspective. Successful management will be adaptive.

3. *Large stand-replacement disturbances*.–In wilderness areas and on other lands managed as natural areas where large stand-replacement fires historically characterized the fire regime, the challenge is to provide for occurrence of large fires. Concerns about fires escaping wilderness boundaries and public perception of an acceptable fire size will tend to constrain the extent of fire that can be allowed. On nonwilderness lands,

the challenge is to avoid excessive fragmentation caused by intensive small scale cutting and prescribed fire activities. For example, in lodgepole pine forests, creation of many small clearcuts is a departure from the natural fire regime. In this case, the age class distribution of lodgepole pine may be within the limits of natural variability but not the pattern of disturbance on the landscape.

4. *Stand structure diversity in mixed and variable fire regime types*.–These fire regime types are the most complicated and least understood. A wide range of stand structures and landscape patterns are probably within the range of natural variability. Thus, managers may have considerable ecological latitude in designing activities to provide ecosystem products. The challenge is to provide a diversity of stand structures. Tree cutting and prescribed fire will be required to accomplish this. More costly harvesting techniques and layouts than used in the past may be necessary. But a better mix of ecosystem products may result.

5. *Woody plant invasion of grasslands*.–Many ecologists consider the reduced frequency and extent of wildfires on rangelands due to fire protection to be among the most pervasive influences in the United States by non-native peoples (Pieper 1994). The shift to woody plant domination has been substantial during this century. Some woody plants such as honey mesquite become resistant to fire, develop fuel discontinuities, and reduce spread of fire. In time, recovery following fire favors shrubs over perennials (Archer 1994). This can alter the composition of ecosystems to the point that a return to the grassland type becomes nearly impossible or impractical. The challenge is to apply fire on a scale adequate to maintain grasslands. This requires a large scale program of periodic prescribed fire and ability to regulate grazing to insure successful fire treatment and recovery of desired vegetation (Gruell et al. 1986).

In summary, knowledge of fires role in the ecology of wildlands is important to land managers and concerned citizens. The concept of fire regimes can be a valuable means of communicating that knowledge to help managers and the public alike in determining proper ecosystem management strategies.

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THE ROLE OF FIRE IN THE BOREAL FOREST OF INTERIOR ALASKA[1]

M. Joan Foote[2]

ABSTRACT: Fire burns 3,000-1,000,000 acres annually. It is a natural part of the ecology of the boreal forest of interior Alaska. Fire alters the site, growing conditions on the site, site resiliency, and the habitat of users of the site. It promotes site productivity by recycling nutrients, warming soils, melting permafrost, and exposing patches of mineral soil which make excellent surfaces for germinating seeds. It maintains landscape diversity and promotes young, highly productive forests and high quality food material. However, the unprotected mineral soil may erode and stability of some of the ice-rich permafrost sites is destroyed, at least for a time.

INTRODUCTION

Interior Alaska is bounded by the Brooks Range to the North, coastal tundra to the West, the Alaska Range to the South, and artificially by the Canadian Border to the East. Six tree species occur in the boreal forest of interior Alaska. Quaking aspen (*Populus tremuloides*) dominates on warm, dry slopes, white spruce (*Picea glauca*) on warm, well-drained slopes, and paper birch (*Betula papyrifera*) on slightly cooler and more moist slopes. Black spruce (*Picea mariana*) and larch (*Larix laricina*) dominate on the cooler and wetter sites. Balsam poplar (*Populus balsamifera*) occurs mostly on the floodplain (Viereck 1973). Forest of mixed species are common. Forest floors contain tall and low shrubs, herbs and mosses.

Interior Alaska lies in the zone of intermittent or discontinuous permafrost. Ice-rich permafrost is best developed on well shaded, well-insulated sites. Ridges and buildings provide excellent shade; vegetation, especially feathermosses and sphagnum, provides excellent insulation. Permafrost occurs on most north-facing slopes, especially where black spruce and feathermoss or sphagnum are present.

Succession in interior Alaska is frequently initiated by fire. Within days of the fire new shoots and seedlings appear. Firemoss (*Ceratodon purpureus*) and marchantia (*Marchantia polymorpha*) quickly invade areas of exposed mineral soil. Invasion continues for 1-5 years. If a species does not establish during this period its influence during the next 40-70 years will be minimal. Herbs dominate the landscape for 1-10 years and tall shrubs for the next 10-20 years. These stages are followed sequentially by a young tree stage that is usually dense, a hardwood stage, a white spruce stage, and either a black spruce/feathermoss or a black spruce/sphagnum stage (Foote 1983). Stages may be skipped or abbreviated; succession may stagnate at any stage if species fail to establish or are killed. Succession may also be terminated at any stage by

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CONTENTS

Page

Page